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(54) A cooling centrifuge with exchangeable rotors

(57) A cooling centrifuge has cooling which is controlled as a function of temperature deviation. To improve the control behaviour and to prevent temperature overshoots, the gain of an amplifier (11) provided in the control loop is influenced. The gain is changed with rotors depending on their respective rotational speed and their heat-generating capability so that, with these rotors, the coolant supply is increased or reduced almost without delay even with small temperature differences.

Fig. 2

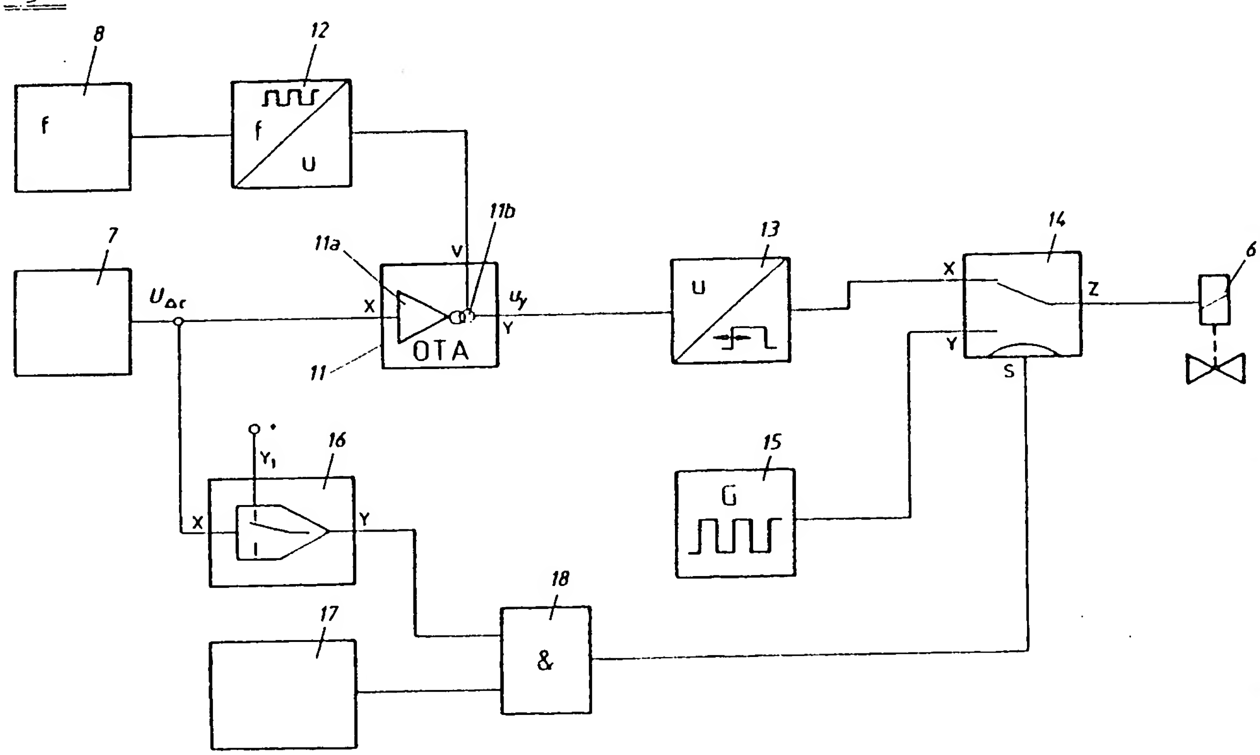

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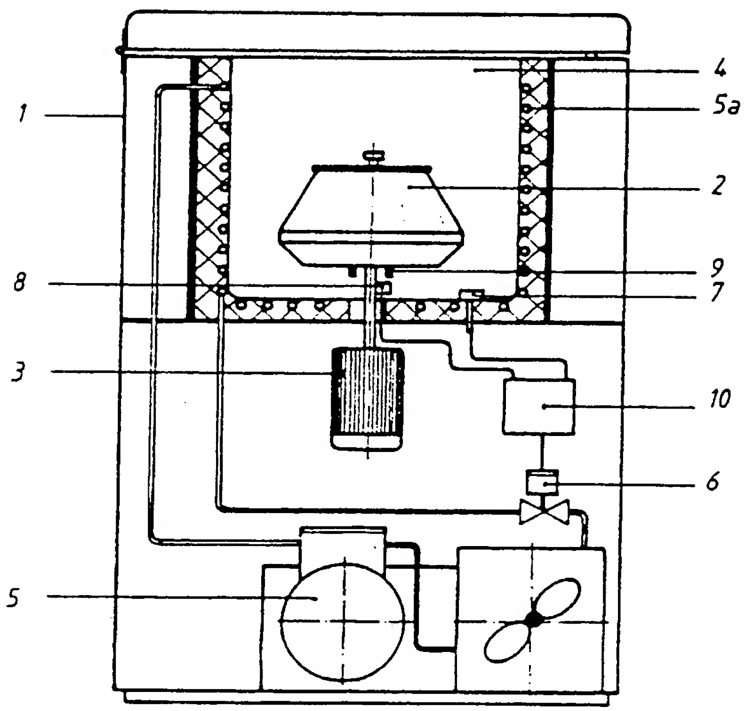
Fig. 1



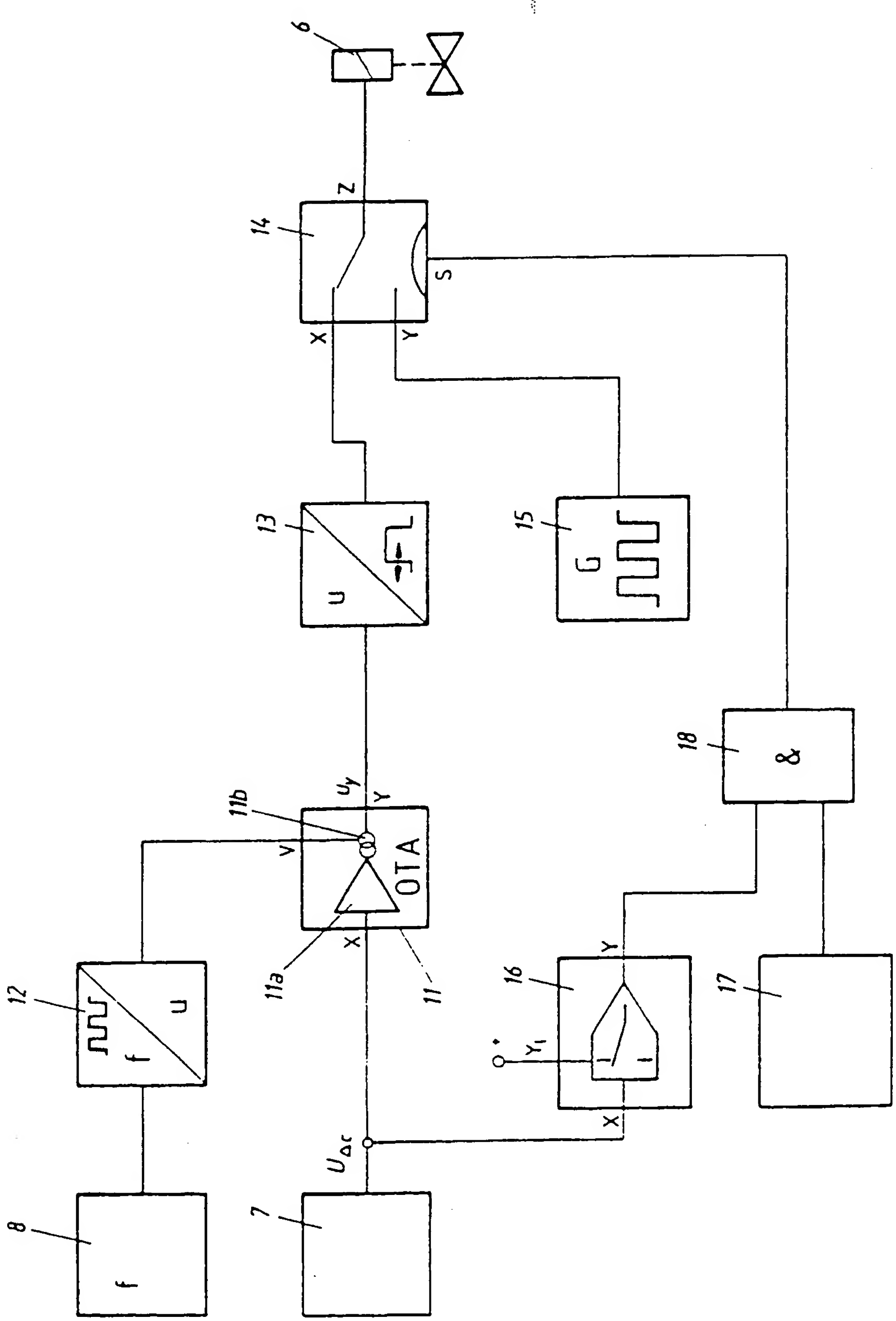

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Fig. 2

Fig. 3

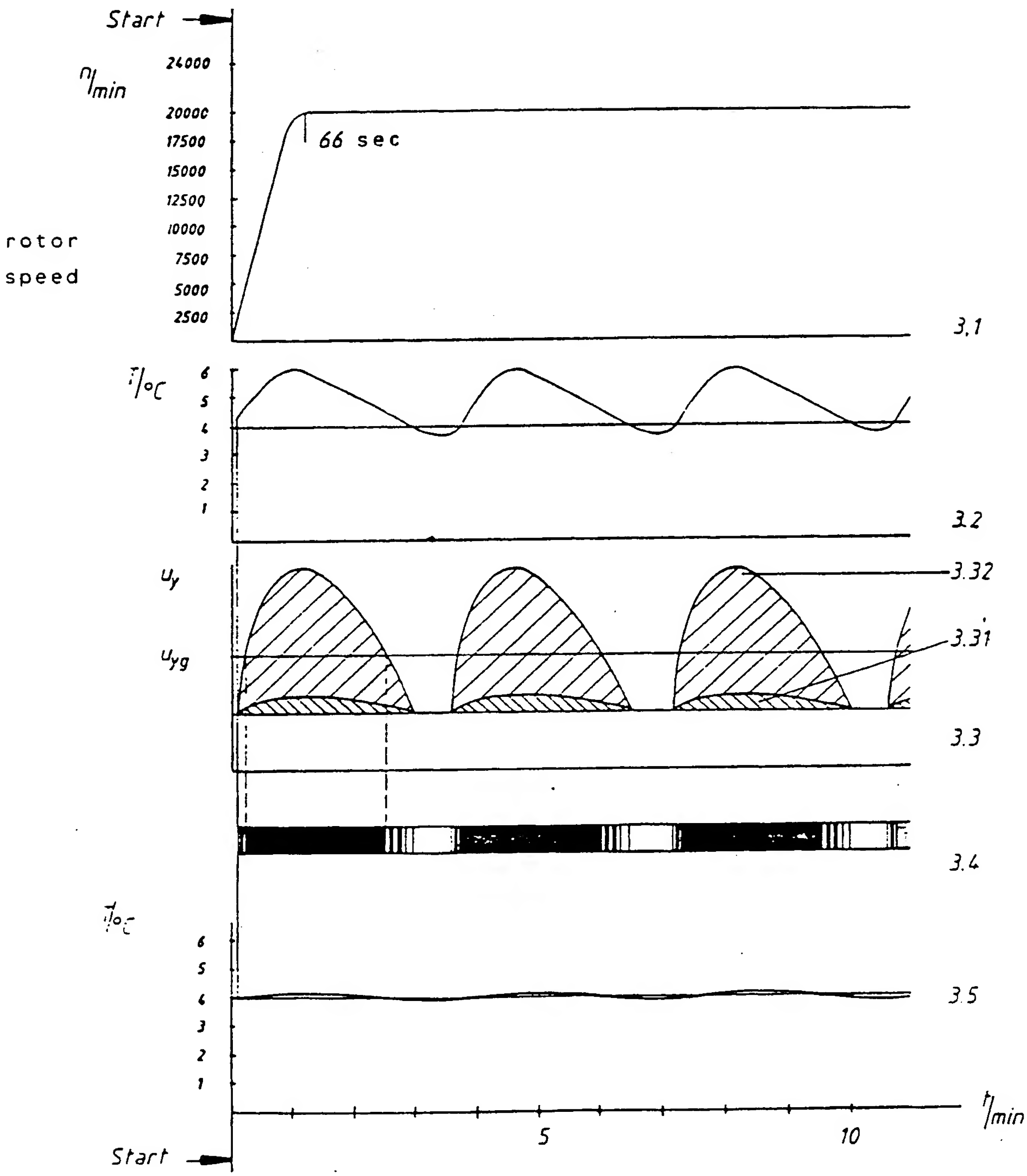

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Fig. 4

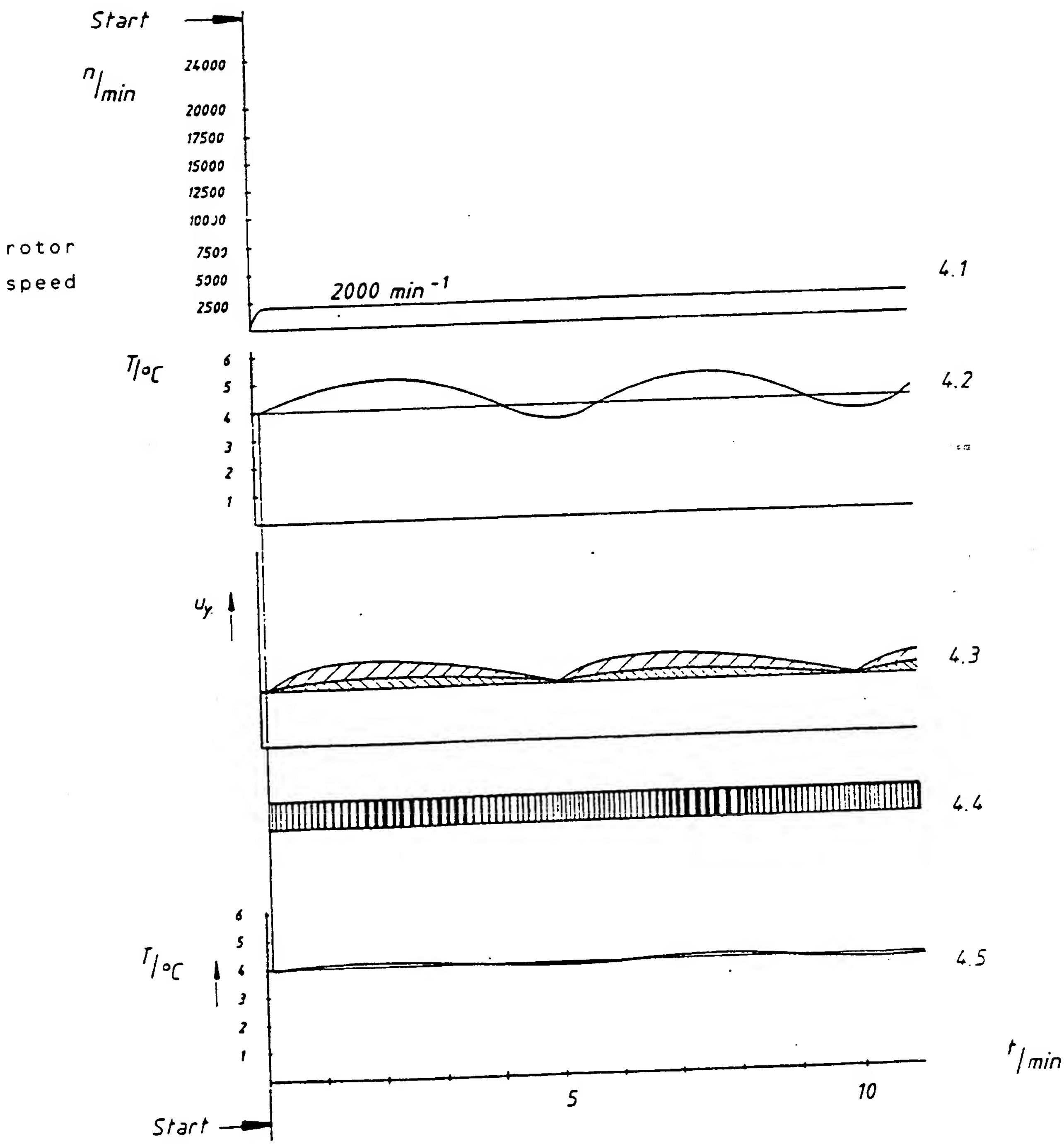

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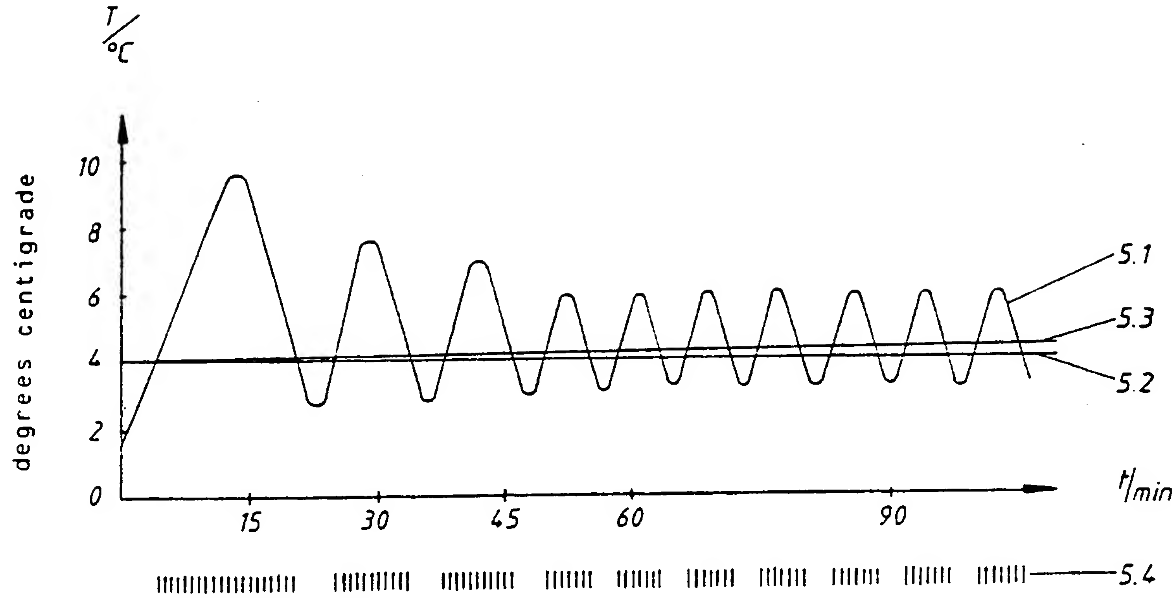
Fig.5



SPECIFICATION

A cooling centrifuge with exchangeable rotors

The invention relates to a cooling centrifuge having exchangeable rotors of different heat-generating capability, a controllable cooling device and a control circuit consisting of a temperature sensor which detects the actual temperature, a comparator which generates a control variable by comparing the actual temperature with a reference temperature, and an amplifier for generating a correcting variable which corresponds to the control variable and which controls a correcting element of the cooling device.

Such centrifuges are used in medical and similar laboratories for separating natural or laboratory-produced material to be centrifuged from components of differing density, with the aim of separating components of the material to be centrifuged as much as possible from accompanying substances, at different temperatures, or of quantitatively detecting one of the phases involved (see DIN 58 970, Part 1/No. 1).

In high-speed cooling centrifuges which are operated at rotational speeds of up to approximately 25,000 revolutions/minute, the material to be centrifuged must maintain an accuracy of ± 1°C within a range of 0 to 25°C at an environmental temperature of 15 to 32°C according to DIN regulations (see DIN 58 970, Part 3).

For this purpose, effective quick-response cooling devices are necessary since a not inconsiderable frictional heat is generated especially at high rotational speeds at atmospheric pressure, which must be rapidly dissipated in order to maintain the prescribed temperature. In this context, the cooling devices and their controls must be designed in such a manner that the prescribed temperature is maintained even with rotors of different dimensions, that is to say rotors having different heat-generating capability.

On the other hand, the temperature should be maintained constant at low rotational speeds, that is to say within a range of 200 to 2,000 revolutions/minute and even at standstill. For this operating condition, only about one hundredeth of the maximum required cooling power is needed since little or no frictional heat occurs. In addition, the heat exchange between the cooled rotor chamber and the rotor is reduced because of the missing airflow, the temperature sensor also disadvantageously detecting the actual temperature with a greater time delay because of the lack of air movement. These circumstances can lead to too much cooling being produced at low rotational speeds or during rotor standstill and the frequently very valuable material to be centrifuged becoming unusable because it is frozen.

In the other extreme case, the sensor detects the heating of the rotor too late at low rotational speeds or during rotor standstill so that the rotor chamber temperature increases too much.

In order to reduce the frictional heat, cooling centrifuges are used in which high-speed rotors move in a partial vacuum. Because of the reduced heat generation, such cooling centrifuges can have weaker cooling systems. However, this does not solve the abovementioned problems since the heat-generating capability depends on the dimensioning of the exchangeable rotors and on the respective rotational speed of the rotors also in this case. In addition, cooling centrifuges working in a partial vacuum produce additional problems in that detection of the air temperature with a temperature sensor arranged in the rotor chamber takes place with greater delay because of the reduced air density.

In order to counter this disadvantage, temperature measuring devices are used which detect the rotor temperature not indirectly via the air temperature, but directly via heat radiation, especially in ultracentrifuges working at very high rotational speeds, namely at rotational speess of the order of magnitude of 20,000 to 80,000 revolutions/minute. Because the radiation energy is low, especially at low temperatures, such devices are elaborate, sensitive and, also very expensive so that they cannot be considered for laboratory centrifuges of the type initially mentioned.

In order to improve the heat dissipation, particularly in multichamber centrifuges for blood, an hydraulic seal has already been proposed which is intended to transfer the heat generated in the course of the centrifuging process in the rotating drum to a fixed heat (see German DE-GM 75 40 083). Since the heat generated fluctuates between a factor of 1 and 100, depending on the rotational speed and rotor dimensions, this measure will not be adequate for cooling centrifuges for general use.

The same applies to the proposal of DE-OS 26 11 679 according to which the housing is provided with air passages which are altered according to the rotor used so that the heat dissipation is better matched to the rotors having different dimensions.

The control characteristics can be better matched to the varying initial situations only by directly influencing the cooling device. Thus it is already known to conduct the coolant via a controlled three-way solenoid valve by means of which, after delayed detection of the actual temperature by the temperature sensor, the coolant is conducted past the cooling chamber in a bypass and back to the cooling circuit when the reference temperature has been reached. Although a cooling device controlled in this manner can be better

matched to differing cooling situations, it is still encumbered with the abovementioned defects.

In the device described in DE-AS 23 27 678 unacceptably high temperature overshoots occurring with a heated centrifuge rotor are prevented by the following measures:

a) use of a rotor having a heat capacity which is considerably greater than the material to be centrifuged;

b) supply of hot air via controlled electric heating elements, taking into consideration the rate of change of the control variable;

c) direct detection of the temperature of the material to be centrifuged by means of a temperature sensor.

Overheating of the samples is prevented by taking into consideration a rate of change of the control variable. However, this document does not reveal any measures for taking into consideration the different dimensions of the rotors and the different rotational speed.

An object of the present invention is for creating a cooling centrifuge having exchangeable rotors for a large range of operating temperatures in the order of magnitude of from − 20 to 40°C in which, apart from the chamber air temperature, also the rotor size and the final rotational speed and thus the respective heat-generating capability are detected without delay in such a manner that the predetermined reference temperature is maintained for the various applications over a prolonged period of time with only slight deviations. Such cooling centrifuges are needed especially in laboratories for biochemistry, human and animal medicine and for genetic research, the temperature control having to be effective within a range of rotational speed of from 250 revolutions/minute to 25,000 revolutions/minute with rotors of different dimensions in order to be able to carry out all necessary examination with one single unit. Similarly, it is to be possible to keep the temperature in the rotor chamber constant over several hours during a standstill in order to be able to remove the samples without damage by temperature effects, for example the following morning after automatic termination of a centrifuging process during the night.

According to the invention there is provided a cooling centrifuge having exchangeable rotors of different heat-generating capability, a controllable cooling device and a control circuit consisting of a temperature sensor which detects the actual temperature, a comparator which generates a control variable by comparing the actual temperature with a reference temperature, and an amplifier for generating a correcting variable which corresponds to the control variable and which controls a correcting element of the cooling device, characterised by a detector device which generates, without delay, a controlling variable which is characteristic of the instantaneous rotational speed and the heat-generating capability of the respective rotor, and means for varying the gain of the amplifier as a function of the heat-generating capability.

As a result of this measure, the cooling is controlled not only as a function of the temperature difference between actual and reference temperature but in addition the heat-generating capability of the respective rotor is taken into consideration due to the fact that the gain and thus the sensitivity of the control loop is influenced. By heat-generating capacity is meant in this case the change in air temperature detected with the temperature sensor arranged in the chamber in a certain time at constant reference rotational speed and identical initial rotor temperature. This heat-generating capability, which is very difficult to treat mathematically, affects the frictional heat which is produced when the rotor is running and which depends on the following parameters:

a. Design shape of the rotor.

b. Material properties, especially finish of the rotor surface.

c. Mean peripheral speed of the rotor surface,

d. Ratio of rotor volume to chamber volume, that is to say air volume present in the chamber with rotor inserted.

e. Ratio of heat storage capacity of rotor and rotor chamber.

The change in control behaviour proposed by the invention has the effect that stronger and thus more rapidly effective cooling is produced in rotors in which greater heating is to be expected as a result of the design and the higher final rotational speed.

However, the consequence of this is also that, when the temperature drops below the prescribed reference value, the cooling is interrupted more rapidly, that is to say with less delay. This prevents too much heat from being removed from the rotor chamber which can result in the abovementioned dangerous undercooling of the samples.

In a particularly simple manner, the invention can be implemented in cooling centrifuges which have a detector device of the kind used in the invention. This is because cooling centrifuges are already on the market in which the permissible maximum rotational speed is limited, as protection against excessive speed, by means of a detector device and a limiter circuit such as is suitable for carrying out the proposal according to the invention. In this arrangement, use is made of the fact that the permissible maximum rotational speed, like the heat-generating capability, depends on the rotor design so that, to a first approximation, the smaller the permissible maximum

rotational speed resulting from rotor strength and design, the greater the heat-generating capability.

Cooling centrifuges having detector devices suitable for this purpose are marketed, for example under the name Hermle ZK-400.

In these cooling centrifuges, the rotor already has identifying elements which, during the rotation of the rotor, generate in a sensor a pulse sequence having a frequency which is proportional to the instantaneous rotational speed, the number and/or arrangement of the identifying elements being associated with the rotor dimensioning and thus indirectly with the heat-generating capability. The pulse sequence generated by the receiver is converted also in the known cooling centrifuges into a controlling variable which in this case, however, is only used to drive the rotational-speed limiter circuit. According to the proposal according to the invention, the controlling variable converted into an analog quantity is utilized for influencing the gain of the amplifier provided in the control loop.

In this arrangement, identifying elements can be reflectors which reflect a radiation, generated by a signal source, in the form of signal pulses to a signal transducer connected to the receiver input. In this arrangement, the signal source can generate radiations of different wavelength. If a light source is used as the signal source, the reflectors consist of mirrors.

However, according to a further proposal of the invention, the identifying elements can themselves be active "radiators", for example permanent magnets the field of which is detected during the rotor rotation with a transducer provided in the input circuit of the receiver, for example an induction loop, a magnetoresistive sensor or similar.

In principle, any cooling device the temperature of which can be controlled is suitable for cooling. However, it is of advantage to use a cooling device which follows the control as much as possible without inertia. For this purpose, the preferred suitable cooling device is one in which the coolant is injected in the form of pulses into the cooling coils, associated with the rotor chamber, since this allows the cooling to be rapidly and effectively influenced by means of the duration of the injection pulse. In addition, a commercially available and thus inexpensive valve of comparatively simple construction can be used for this purpose instead of a costly valve the flow of which can be varied in analog manner.

This is why such a cooling device is provided in the cooling centrifuge described. For the injection of the coolant, a commercially available controllable solenoid valve is adequate which is driven by a pulse-width modulated pulse sequence. The latter is suitably generated by a pulse width modulator the modulation factor of which is determined by the output signal of the amplifier.

The abovementioned measures provide highly variable cooling, which can be controlled with only little delay, during the rotation of the rotor.

However, since no signal is supplied by the detector device during rotor standstill, this control system is not suitable, without further measures, for providing cooling during rotor standstill.

For this purpose, further according to the invention, a pulse generator is provided which is activated only by rotor standstill and drives the solenoid valve with constant-width and -frequency pulses when the rotor chamber temperature deviates from the reference temperature. Since, during rotor standstill, no frictional heat is generated and consequently only the heat loss must be compensated, it is sufficient to open the solenoid valve at greater time intervals for a short pulse duration, that is to say to use a pulse generator which generates a pulse sequence which has a greater period duration than when the rotor is running. It has been shown to be particularly advantageous if the duration of a period is about five times greater during rotor standstill than when the rotor is running and the pulse duty factor, that is to say the ratio between the pulse duration and pulse period, can be about 100.

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a diagrammatic representation of a cooling centrifuge according to the invention,

Figure 2 is the electric block diagram of the control circuit for the centrifuge,

Figure 3 consists of diagrams for representing the changes in rotational speed, temperature and pulses as a function of time at a high final rotational speed,

Figure 4 consists of diagrams similar to Fig. 3 at a low final rotational speed, and comprising the following time-related values:

3.1 and 4.1:	rotational speed of rotor,
3.2 and 4.2:	temperature in the rotor chamber, measured by the temperature sensor,
3.3 and 4.3:	output voltage of the controlled amplifier,
3.4 and 4.4:	control pulses generated by the pulse modulator,
3.5 and 4.5:	rotor temperature, and

Figure 5 shows the temperature variation during rotor standstill, comprising:

5.1 rotor chamber temperature

5.2 reference rotor temperature,

5.3 actual rotor temperature,

5.4 pulses generated by the pulse generator.

The basic configuration of the cooling centrifuge is known and is illustrated in Fig. 1.

In a housing 1, a rotor 2, here constructed as an angle rotor, is arranged inside the rotor chamber 4. The rotor is interchangeable and can be replaced by rotors of different dimensions and construction. The rotor is driven by a drive motor 3 the rotational speed of which can be varied. A cooling unit 5 is used for cooling the rotor chamber 4. The cooling agent by this unit 5 is conducted via an electromagnetically controllable valve 6 to the cooling coils 5a surrounding the cooling chamber 4. The actual temperature is monitored by means of a temperature sensor 7 provided in the rotor chamber 4. The chamber temperature detected by means of the temperature sensor 7 is compared in a control circuit 10 with a predetermined reference temperature. If a temperature difference occurs, the solenoid valve 6 is driven for controlling the coolant supply; that is to say it is either shut off or opened.

A detector device consisting of a stationary sensor 8 and identifying elements 9, which are arranged at a distance from each other in a circle on the rotor 2, is provided for detecting the actual rotational speed of the rotor. The identifying elements 9 rotating with the rotor are photo-electrically, electro-magnetically or electrostatically scanned by the sensor 8. For example, the identifying elements can be reflectors which reflect the light of a light source, not shown, to a photoelectric transducer arranged in the input circuit of the receiver, for example a photocell or a phototransistor. Active, identifying elements in the form of permanent magnets can also be used which induce, with every revolution, a number of pulses corresponding to the rotor size in an inducation loop arranged in the input circuit of the sensor, a magnetoresistive sensor or similar. Each rotor has a maximum permissible rotational speed depending on its dimensions and mass. The arrangement or number of identifying elements 9 corresponds to this maximum rotational speed so that the signal is generated in the sensor and which is fed to the control circuit 10 can be directly used for protection against excessive rotational speed of the rotor drive. In this arrangement, the lower the maximum permissible rotational speed the higher the number of identifying elements 9.

The limiting of excessive rotational speed is known. The novel factor is the influencing of the control behaviour of the control circuit 10 as a function of rotational speed and heat-generating capability, proposed with the present invention.

This is effected by the control system illustrated with the block diagram of Fig. 2.

The temperature sensor 7 is used to detect the actual temperature existing in the rotor chamber 4, which is compared with an adjustable reference temperature value. If the temperature deviates from this reference value, the temperature sensor 7 generates a positive or negative control voltage $U\Delta T$ the magnitude of which corresponds to the temperature difference ΔT. The control voltage $U\Delta T$ is amplified by means of an amplifier 11 which, in the illustrative embodiment, consists of an operational amplifier 11a and a controlled current source 11b. In the illustrative embodiment explained, the variable gain is between 10 and 50. At the output Y of the amplifier 11, an analog output signal appears which is amplified by the gain factor with respect to the signal at the input X and which is fed to the primary side of an analog/digital converter operating as the pulse-width modulator 13. On its secondary side, this A/D converter provides pulses of constant clock period, that is to say constant frequency, but of variable, that is to say modulatable, pulse-width. In the illustrated embodiment, a clock period of 10 seconds was selected with a modulation percentage of from 0 to 100%. These pulses are used to drive the electro-magnet of the solenoid valve 6, situated in the coolant circuit. A change-over switch 14 described hereinafter is provided between the pulse width modulator 13 and the solenoid valve 6. The gain of the amplifier 11 can be controlled by means of a signal derived from the actual rotational speed when the rotor is running.

As explained above, a pulse sequence is generated in the receiver 8 which is dependent on the rotational speed and the number of identifying elements 9 and thus indirectly on the heat-generating capability of the rotor and which is converted by means of a digital/analog conerter 12 into an analog output signal. This output signal is fed to the control input V of the amplifier 11 which means that the gain of the current source 11b is controlled as a function of the rotational speed and heat-generating capability. At high rotational speed, the receiver 8 produces a high-frequency pulse sequence so that the gain of the amplifier 11 is increased. With a high-mass rotor, to which a larger number of identifying elements is allocated, the gain is increased even at lower frequencies. The consequence is in both cases that the voltage formed at the output Y of the amplifier 11 rises or falls proportionally even to a small difference between actual and reference temperature which causes the pulse-width, which can be changed between 0 and 100%, for the on-time of the solenoid valve 6 to be proportionally increased or reduced.

The temperature variations and the interactions occurring when a centrifuge rotor is running are explained with the aid of time-synchronous diagrams for a comparatively high rotational speed of 20,000 revolutions per minute in Fig. 3 and for a low rotational speed of 2,000 revolutions per minute in Fig.

4. In both cases, a rotor precooled to 4°C is inserted into the centrifuge.

Curve 3.1 shows the running up of the rotational speed from 0 to 20,000 revolutions/minute which is reached after 66 seconds. As is clearly shown by curve 3.2, the chamber temperature detected by the temperature sensor 7 rises to 6°C as a result of the frictional heat of 4. Naturally, because of the thermal inertia of the rotor this air temperature does not correspond to that of the material to be centrifuged which is located in centrifuging vessels of the rotor. In order to prevent the temperature of the material to be centrifuged from increasing in accordance with the temperature rise of curve 3.2, cooling measures are required. Coolant is increasingly injected by means of the solenoid valve 6 in accordance with the temperature difference ΔT. The coolant supply is controlled as a function of the output voltage, present at Y, of the amplifer 11 the variation of which voltage is shown in curve 3.31 without the effect of the correcting variable utilized according to the invention. Curve 3.31 clearly shows that, if this controlling variable were used, the control would be too insensitive, that is to say it either could not respond quickly enough to temperature changes or the coolant supply is not reduced or interrupted rapidly enough. In both cases, the material to be centrifuged would not be guaranteed to be at constant temperature.

The correcting variable proposed with the invention and derived from the actual rotational speed and a parameter which is characteristic of the thermal inertia causes the gain factor of the amplifier 11 to be increased in such a manner that at the output Y of the amplifier 11a control signal is generated which is proportional to the temperature difference detected and the variation with time of which is illustrated by means of curve 3.32 in Fig. 3.3. This curve clearly shows that at high rotational speeds leading to large-scale heat generation and/or with large-volume rotors having a high heat-generating capability, the required control response occurs in good time with delay in spite of the fact that the air temperature in the rotor chamber shows only comparatively little change.

In the embodiment illustrated, the pulse width of the signal present at the output of the pulse modulator 13 is 100% when the voltage Uy has reached the value Uyg. This has the effect that the solenoid valve 6 is open during the period in which the control voltage Uy is above the limit value Uyg, as is clearly shown by the bar diagram of item 3.4 which represents the opening times of the solenoid valve 6. During this time, coolant is continuously supplied whilst before and afterwards the coolant is injected only by pulse-by-pulse, with increasing or decreasing pulse duration. The result of this control measure, that is to say the temperature variation with time within the material to be centrifuged, is illustrated by the diagram of item 3.5. In the illustrative embodiment explained, the sample temperature fluctuated by approximately 0.3°C at the set temperature of +4°C.

Corresponding processes and temperature characteristics are shown when the same rotor is used but at a lower maximum rotational speed, that is to say a rotational speed of 2,000 revolutions per minute, in the diagrams of Fig. 4. As shown by curve 4.1, the final rotational speed is already reached after a short time.

The rotor chamber temperature 4.2 as detected by the temperature sensor 7 also fluctuates by about 2°C under the influence of the frictional heat and the controlled cooling. Due to the thermal inertia of the rotor, this temperature change has no effect on the material to be centrifuged. Its temperature is constant at about 4.5°C and fluctuates by about 0.3°C, as is clearly shown by diagram 4.5.

For the abovementioned reasons, the lower rotational speed of the rotor results in a reduced gain factor of the amplifier 11 so that its output voltage Uy illustrated with the curve 4.3 changes to a lesser extent as a function of the rotor chamber temperature. The output signal Uy does not now reach the limit value specified in diagram 3.3 so that the pulse width of the pulse sequence generated at the output of the pulse modulator 13 never reaches 100% and, in consequence, the solenoid valve 6 is driven only with comparatively short pulses of variable width, as is shown by the bar diagram of 4.4.

When the rotor is standing still, the transducer 12 does not generate any control variable so that the gain of the amplifier 11 would become 0 and cooling would be stopped. It is not sufficient, however, to limit the gain of the amplifier 11 to a certain value for this situation since other conditions exist for the following reasons.

Since the frictional heat is missing when the rotor is standing still, only dissipation heat must be compensated, this being largely independent of rotor size. On the other hand, the temperature sensor 7 responds extremely slowly because of the missing air flow in the rotor chamber. If the coolant supply were controlled only via the control loop consisting of temperature sensor 7, amplifier 11, pulse modulator 13 and solenoid valve 6, unacceptable temperature fluctuations would be unavoidable.

For this reason, the temperature is controlled in a different manner when the rotor is standing still.

When the rotor is standing still, the pulse generator 15 is connected via the change-over switch 14 to the control input of the solenoid valve 6. As is shown in the diagram 5.4 in

Fig. 5, the pulse generator 15 generates pulses having a lower pulse sequence frequency and a constant pulse width. Thus, in this embodiment, the pulse duty factor, that is to say the ratio between pulse duration and pulse period, is 0.5 seconds/50 seconds = 1:100. The solenoid valve 6 is driven by these pulses until the preset reference temperature is reached. In order to implement this control condition, the control input of the change-over switch 14 is connected to the output of the AND gate 18. The first input of the AND gate 18 is driven by the temperature comparator 16 which produces a signal whenever the temperature sensor detects a deviation of the actual temperature from the reference temperature.

The second input of the AND gate 18 is controlled by a signal generator 17 which generates a signal during a rotor standstill. Consequently, if unacceptable temperature deviation and rotor standstill coincide, the output of the pulse generator 15 is connected via the change-over switch 14 to the control input of the solenoid valve 6. During this time, pulses of coolant are injected until the rotor chamber temperature has reached the reference value again.

These control and regulating processes are illustrated by means of the diagrams in Fig. 5. Curve 5.1 shows the fluctuations detected by the temperature sensor 7 of the rotor chamber temperature. Curve 5.2 shows the variation of the actual temperature of the material to be centrifuged whilst line 5.3 gives the reference temperature of the material to be centrifuged. As a rule, the temperature drop shown of 0.2°C/hour is permissible but can be reduced with corresponding control effort.

The diagram of 5.4 illustrates the control pulses which become effective at the control input of the solenoid valve 6.

In the block diagram of Fig. 2, only the assemblies necessary for explaining the invention are shown. These assemblies can be processor circuits which can be appropriately programmed.

CLAIMS

1. A cooling centrifuge having exchangeable rotors of different heat-generating capability, a controllable cooling device and a control circuit consisting of a temperature sensor which detects the actual temperature, a comparator which generates a control variable by comparing the actual temperature with a reference temperature, and an amplifier for generating a correcting variable which corresponds to the control variable and which controls a correcting element of the cooling device, characterised by a detector device which generates, without delay, a controlling variable which is characteristic of the instantaneous rotational speed and the heat-generating capability of the respective rotor, and means for varying the gain of the amplifier as a function of the heat generating capability.

2. A cooling centrifuge according to Claim 1, wherein a sensor is arranged adjacent the rotor, the rotor is provided with active or passive identifying elements which during the rotation of the rotor generate in the sensor a pulse sequence having a frequency which is proportional to the instantaneous rotational speed, the number and/or arrangement of the identifying elements is associated with the heat-generating capability of the rotor, and the pulse sequence generated by the sensor is converted by means of a digital/analog converter into the analog controlling variable.

3. A cooling centrifuge according to Claim 2, wherein the identifying elements are reflectors which reflect a radiation, generated by a signal source, in the form of signal pulses to a signal transducer connected to the receiver input.

4. A cooling centrifuge according to Claim 2, wherein the identifying elements are permanent magnets and that in the sensor input an induction loop associated with the permanent magnets, a magnetoresistive sensor or similar transducer element is arranged.

5. A cooling centrifuge according to any one of Claims 1 to 4, wherein the amplifier is followed by a pulse width modulator which converts the analog output signal of the amplifier into a pulse width-modulated pulse sequence, and the output of the modulator controls a solenoid valve through which coolant is injected in the form of pulses into cooling coils provided in the area of the rotor chamber.

6. A cooling centrifuge according to any one of Claims 1 to 5, comprising a limiter circuit which limits the permissible maximum rotational speed of the rotor drive in accordance with the arrangment of the identifying elements characteristic of the rotor.

7. A cooling centrifuge according to Claim 5 and Claim 6, comprising a pulse generator which generates control pulses of constant width and frequency for controlling the solenoid valve during rotor standstill, and the output of which is connected to the control input of the solenoid valve when the rotor chamber temperature deviates from the reference temperature.

8. A cooling centrifuge according to Claim 7, wherein the solenoid valve can be driven via a change-over switch the first input of which is connected to the output of the pulse width modulator, the second input of which is connected to the output of the pulse generator, and the control input of which is connected to the output of an AND gate the first input of which is connected to the output of a temperature comparator and the second input of which is connected to a signal generator, controlled by the rotor, for detecting standstill.

9. A cooling centrifuge according to Claim

7 or Claim 8, wherein the duration of a period of the pulse sequence generated by the pulse generator is greater than that of the pulse sequence generated by the pulse width modulator and that it is preferably five times as great as that of the pulse sequence generated when the rotor is running.

10. A cooling centrifuge substantially as herein described with reference to the accompanying drawings.

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